EYEBALL

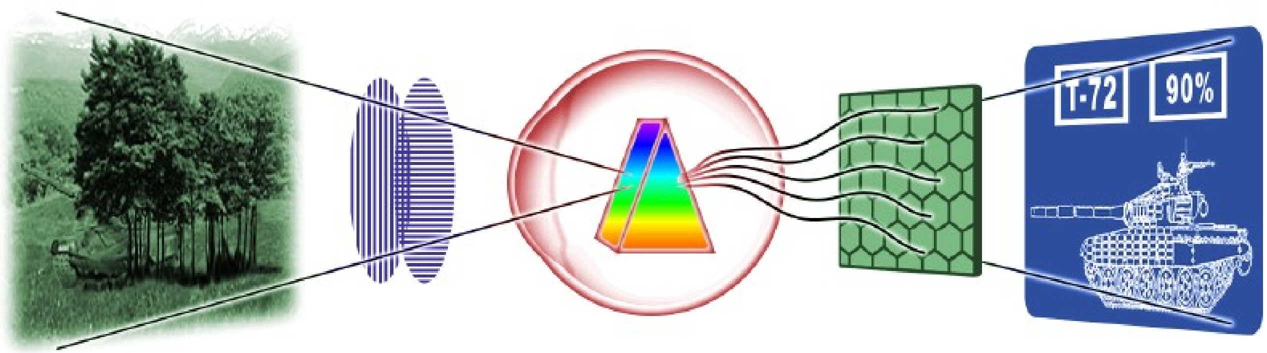
Science Applications International Corporation
An Employee-Owned Company

Raytheon

Veridian
ERIM International

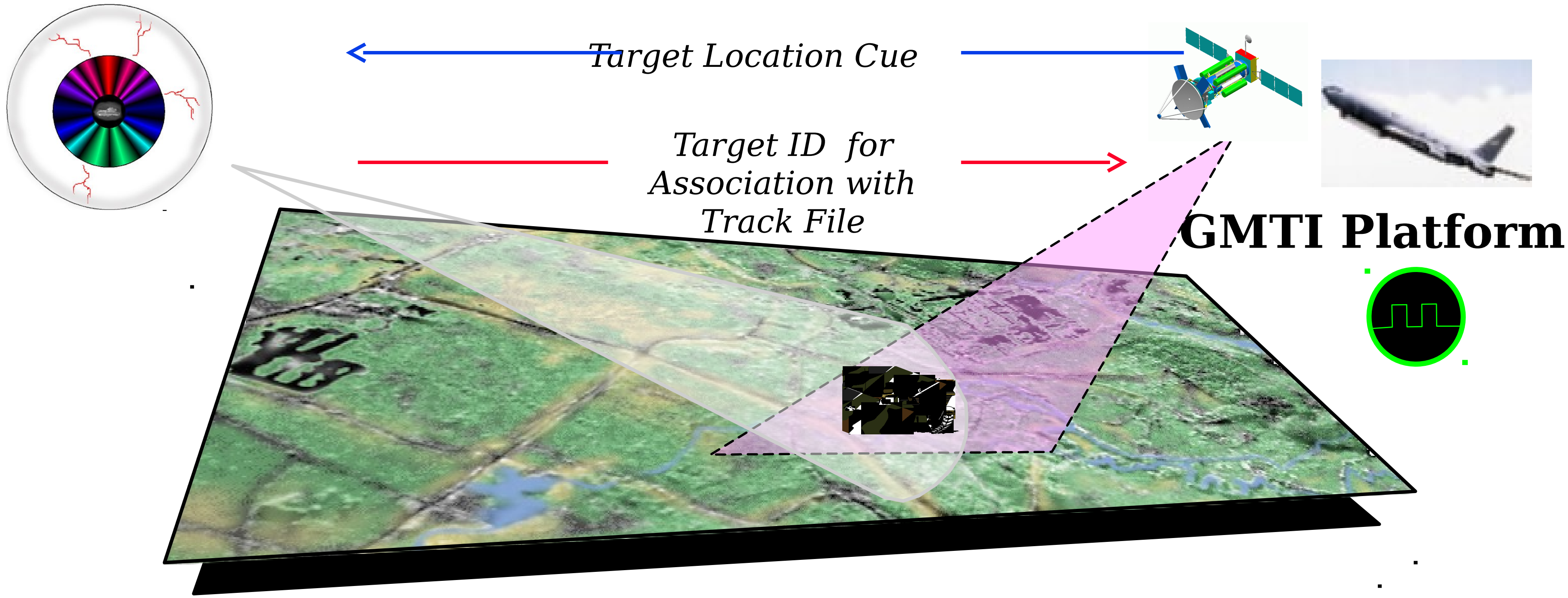
Central MASINT Organization
United States of America

Schafer
Technology Management Division



Eyeball Concept

Cued ID



- Assume: GMTI-SAR provides target location handoff and episodic revisit to track
  - Need to ID targets (day or night) tracked by other means & standoff is essential for access and survivability.
- ***Eyeball sensor provides real time precision aided identification using spatial/ spectral/ polarimetric signature combinations***

Problem Statement

- **Precision target identification is difficult at extended ranges**
- **Trades and sacrifices usually result**
  - Visible versus infrared
    - Infrared required for day/night ID
  - Broadband sensor difficulties
    - Spectral and polarization benefits usually dictate complex sensor
  - Radar (all weather) versus Electro-optical
    - Tracking versus ID – radar and EO ***combined*** is best!
- **ATR is still not an exact science**
  - Assisted target recognition is a worthy goal

- ***Question to answer*:**
  - *What is required in the spectral – spatial – polarimetric domains to conduct effective ID against "difficult targets"?*

Technical Approach

- **4 phase program**
  - Concept Development – year one
  - Phenomenology – year one and year two
  - Ground Based Experiment – sensor testbed development - year three and four
  - Data Analysis – data collection – year three and four
  - Concept Refinement – model validation – year four
- **Start with high-fidelity data and work down**
- **Technical risks: Sensor selection (registration and sensitivity) - proper site selection**

Phenomenology Keys

Spatial

1. Silhouette and Component Intensity Contrast
2. Resolution to Resolve Silhouette/Component Shape

Reflection or Emissivity/Temperature Difference Between Target and Adjacent Clutter

Vulnerable to Low Contrast

Spectral

1. Target Spectral Contrast
2. Clutter Spectral Correlation
3. Unique Target Material Spectral Features

Reflection or Emissivity Spectral Difference Between Target and Adjacent Clutter

Vulnerable to Hohlraum Conditions

Polarimetric

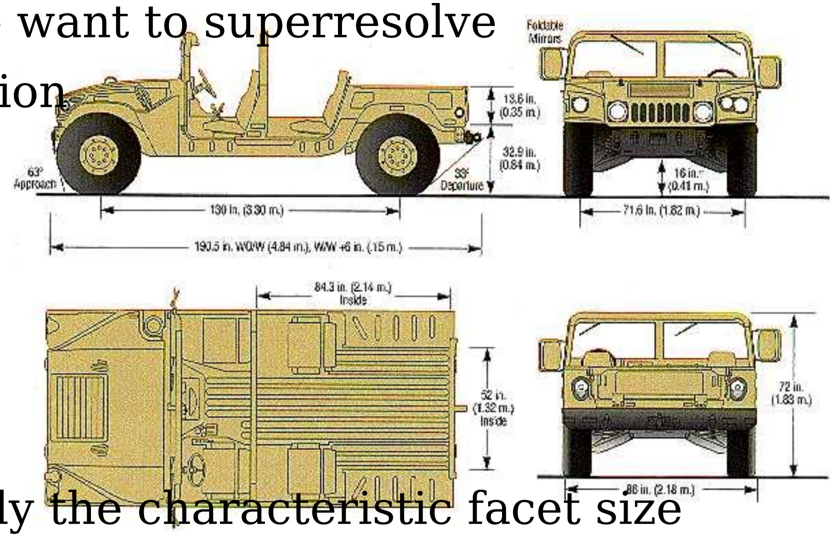
1. Target Polarimetric Contrast
2. Clutter Correlation
3. Unique Target Polarization Orientation Distribution (Shape)

Refractive Index/Roughness Difference Between Target and Adjacent Clutter

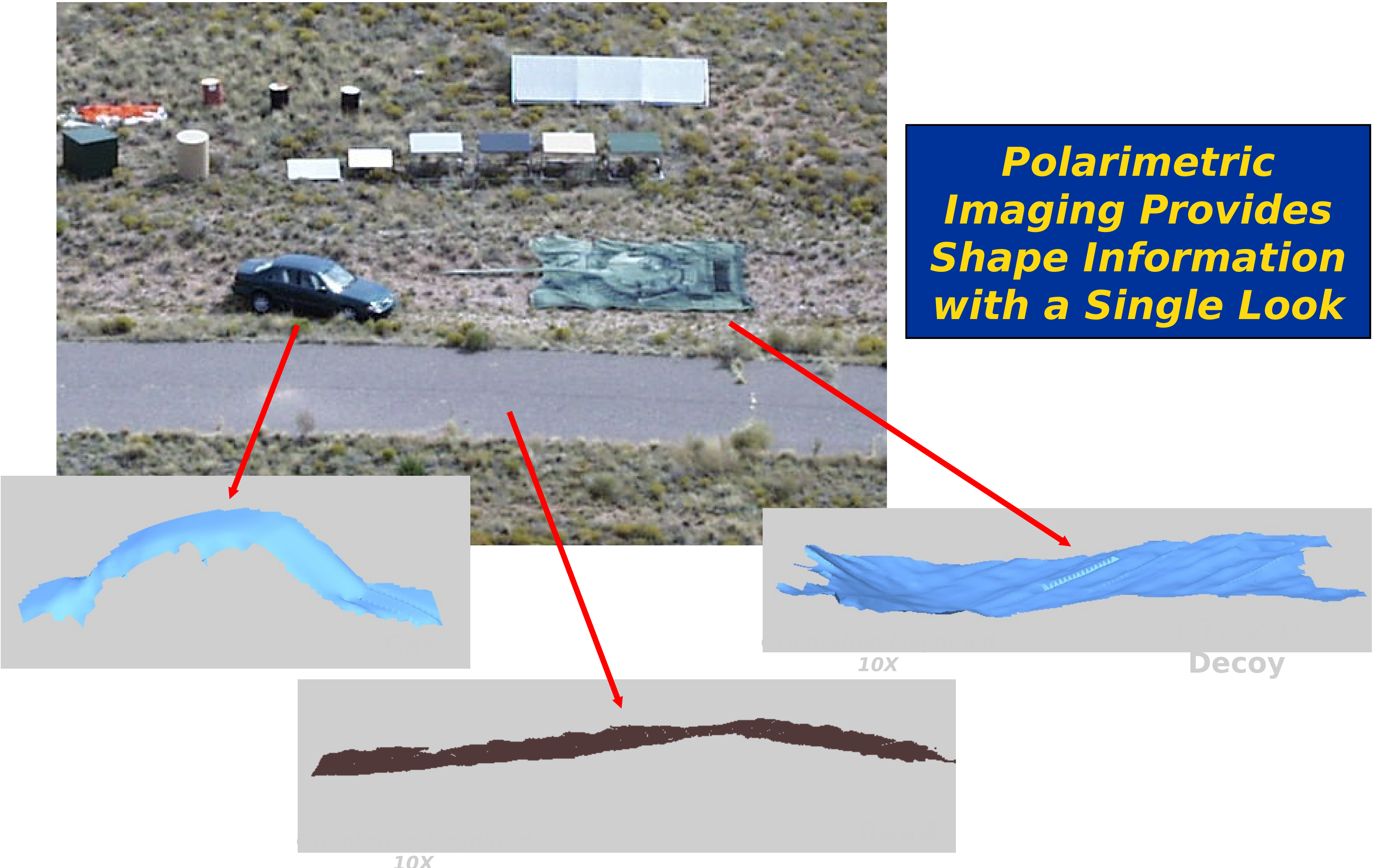
Vulnerable to Hohlraum Conditions

Resolution Elements on Target

- **Key issue—Spatial resolution is important in polarimetry and spectral imaging to keep the signal purity within acceptable limits**
  - Subpixel detection is a nonstarter – we want to superresolve
  - Enough of an issue with pixel registration
- **Assumptions:**
  - diffraction-limited resolution
  - Typical, small-end target: HMMWV
    - 180″ L × 85″ W × 69″ H
    - Ground footprint = 106.2 ft²
  - A pixel should be no larger than roughly the characteristic facet size
    - ~ 1 foot
  - Pixels on target for spatial-only ID
    - 100 pixels—can do ATR
    - 80 pixels—borderline for ATR
    - 50 pixels—cannot do ATR

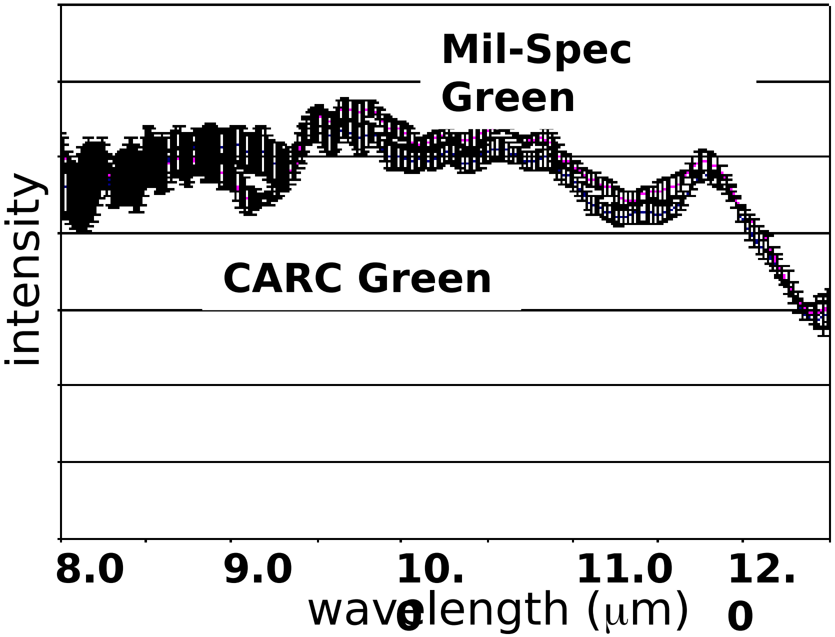


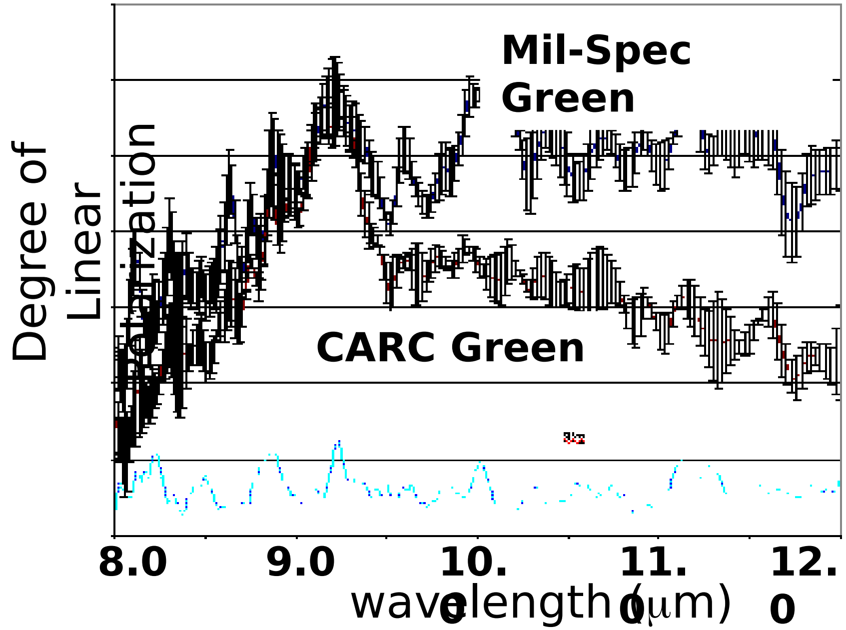
Shape Determination with Long Wavelength Infrared (LWIR)



Polarimetric Imaging Provides Shape Information with a Single Look

Polarization Measurements of Painted Surfaces

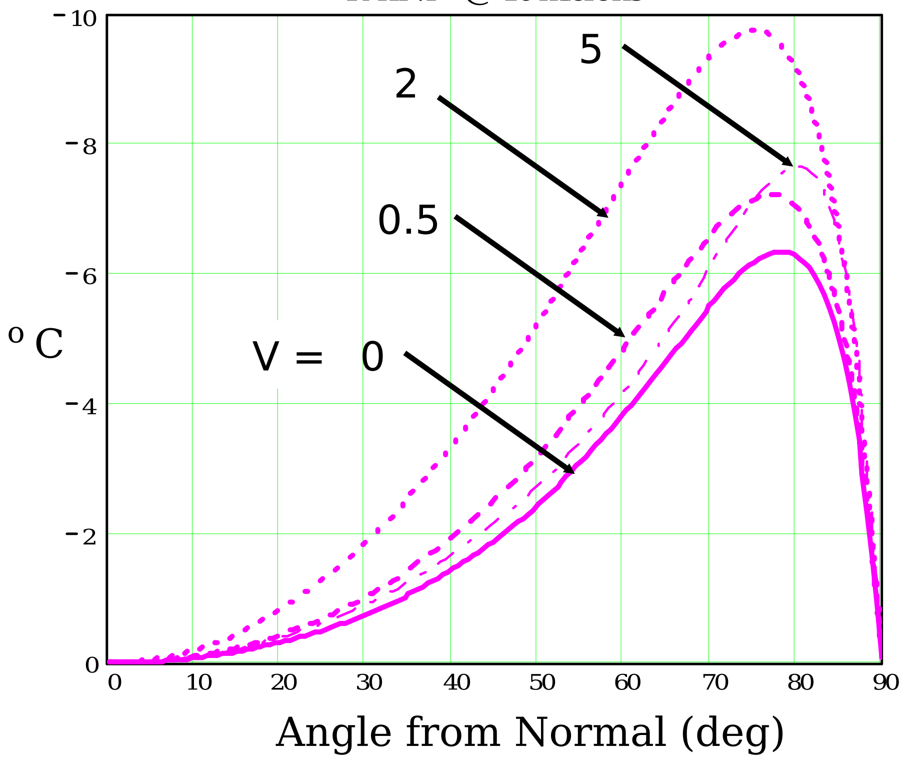


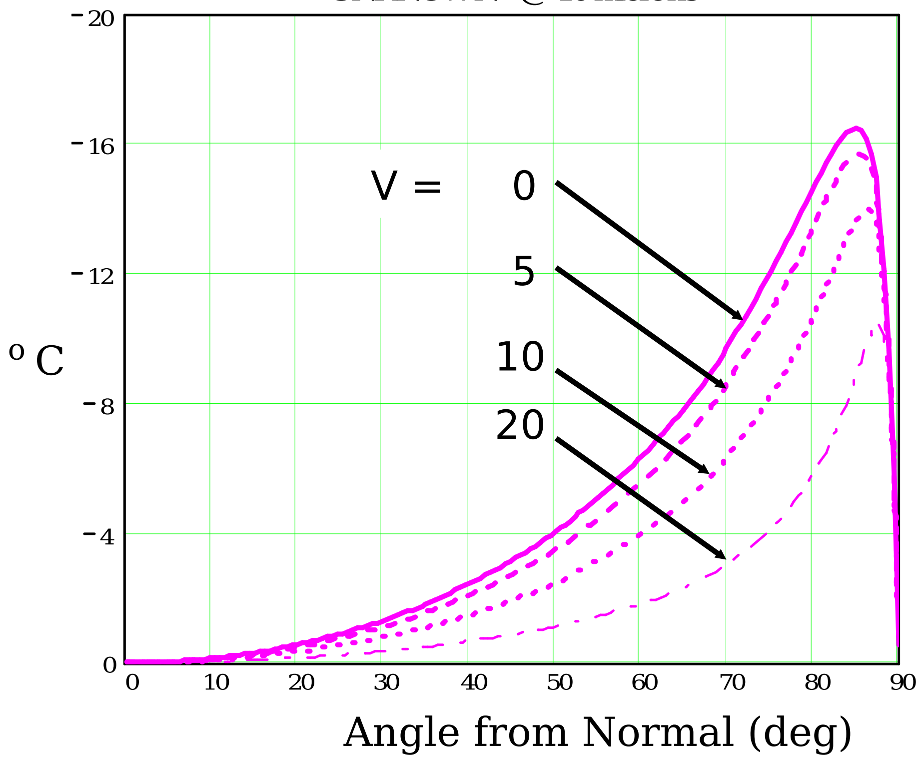


Discrimination of Paint is Possible using Spectral Polarization

Limits on Expected Polarimetric Signatures

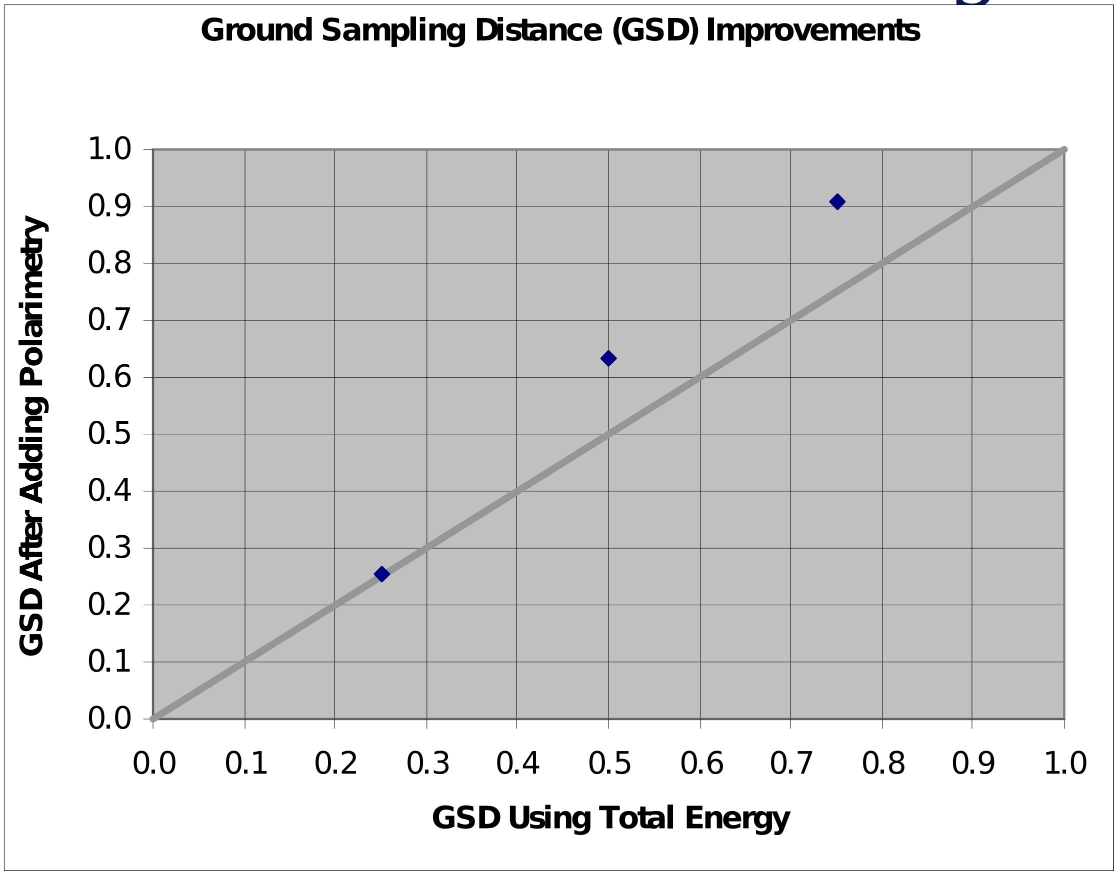
Computed Polarization Signature @ l = 10 µm for a 294 K Painted Metal Surface — Spectral Angle looking @ 250 K Sky





Dielectric "Paint" radiometric signature peaks @ approx. V = 2 then dec
Metal "Unknown" radiometric signature monotonically decreases with in

Results of Modeling Showing the Benefit of Adding Polarimetry



The plotted points represent the Ground Sampling Distance (GSD) required to produce a given target ID capability using total energy compared to the GSD needed for total energy plus polarimetry

- **For high resolution, adding polarimetry did not significantly improve GSD**
  - at GSD = .25 m, GSD was improved to .255
- **As resolution was relaxed, GSD was improved**
  - from .5 m to .63 m
  - from .75 m to .91 m.

Eyeball Ground Experiments

- **Validate IRMA (Infrared Modeling and Analysis)**
  - Pixels on target
  - Spectral channels
  - Polarimetric channels
- **Nov 02**
  - Sensor testing
- **Feb 03**
  - North Oscura Peak experiment
- **Not temporal simultaneous (rotating polarizer)**
- **Affordable**
- **Single angle, multi target condition**

Accomplishments

- **Site inspection and selection- survey completed – North Oscura Peak, WSMR.**
- **Developed 1st principle models for polarization state of light**
  - Thermal self-emission model
  - BRDF model for rough flat surfaces
  - Coordinated model validation with Army TEC, AFRL/VS and NIST activities
- **Using IRMA (InfraRed Modeling and Analysis) as polarimetric image generation tool – limits on polarimetric signatures**
  - Generated LWIR inputs based on polarimetric model
  - Created images that suggest utility of spectro-polarimetric approach
- **Validating models with spectro-polarimetric data from PETSS program**
  - Validating polarimetric emission model
  - Analyzing potential atmospheric impacts on PETSS data quality
- **Modified established ATR tools to handle multidimensional data for use in sensor trade studies**
- **Assembling simulation/analysis test bed - completed examination of aperture size vs. altitude and spectral region to perform conventional target ID**
- **Completed first-principles look at aperture size vs. altitude and spectral region to perform conventional target ID**